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Some Principles for Route Descriptions Derived from Human Advisers

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Abstract

There is a need to make the interface of Route Guidance systems more flexible, so that they can adapt to the specific driver needs. Todays systems are primarily aimed at tourists, and interfaces for drivers that have more experience of a city have not been investigated. In this paper we describe a study with very experienced driver-navigators, where we have deduced principles as to how route descriptions are constructed and expressed by humans. Some of these principles are implementable, and a rough outline of a program is presented. Given a plan of how to go from A to B in a city, the program produces a verbal description of that plan. The goal is to incorporate verbal descriptions in Route Guidance systems, primarily aimed at driver-navigators with some knowledge of the city.

Furthermore, we speculate into what kind of cognitive processes are involved when humans choose and describe routes.

1. Introduction

In the field of Route Guidance, an important and difficult issue is how to describe a route, chosen by the planning part of the route guidance system, to the driver-navigator. We have identified the need of different descriptions for different kinds of drivers [Wærn, Alm]. As a first rough division we can differentiate between drivers who are unfamiliar with a city, like tourists, and drivers who live or work in a city. We name the first group *tourist navigators*, and the other group *citizens* navigators. Of course, there is no clear-cut line between these two groups, you might even belong to both groups in a city, for instance, it you know one part of the city very well, and another part not so well.

For the tourist navigator, it will be necessary to give very detailed route information, preferably during the trip, so that the driver never feels lost and knows exactly what to do in every intersection, as in the LISB system [von Tomkewitsch]. For the citizen navigator, this kind of instructions will be too detailed. Instead an overview of what route has been chosen, and a few helpful instructions while driving give enough guidance. The overview must, for safety reasons be given before the trip starts, as we do not want to interfere with the already complicated driving task. This puts high demands on the presentation *form*, *length* and *content*.

The starting point for the study reported here was a prestudy, reported in [Höök]. We asked 10 persons to describe a route first in verbal form, and then by drawing a map (the order was changed for some subjects). The subjects were encouraged to assume that the experimental leader did know enough about Stockholm to understand a simplified route description. This study showed that people are able to "chunk" a number of roads into one unit. For example, driving from the starting point to the nearest big road, E4, in our experiment, involved four roads. These four roads were "chunked" into the expression: "get down to E4". In the prestudy, we also found that the "chunks" obtained were different in verbal form as opposed to map form.

Apart from the interesting issue of importance of presentation form, we found the chunking mechanism interesting, since it could provide us with a means of reducing the length of a route description and still keep it unambiguous. Some questions were raised: when can something be turned into a chunk? what simplifications are allowed? does the city or the route need to have certain properties in order to lend itself to this kind of chunking?, etc.

In the study, we asked persons who have long experience of a city and who are from time to time asked to give route descriptions (taxi drivers, traffic policemen, etc.), to provide us with route descriptions. It must be emphasised that the study should foremost be looked upon as a data collecting study rather than an investigation into human behaviour. We are interested in finding results that can be implemented, and used as an interface to a route guidance system. In section 5, we shall make a rough outline of how we imagine that the results from the study can be used to make such an implementation. Even so, we have allowed ourselves to speculate upon what kind of mental processing is taking place when the subjects chose and describe routes, which is reported in section 4.

2. Experiment set-up

The experiment was conducted with routes in Stockholm, and the set-up consisted of 10 persons, out of which 5 were taxi-drivers, 2 were born and living in the city, and 3 were traffic policemen. One of the subjects was a woman. The analysis is based on eight of these ten subjects, two tapes were destroyed by the video machine. Note that some of the subjects knew the experimental leaders personally. They were paid SEK 75:-/hour, and the interviews took approximately 1 - 2 hours per subject. One of the subjects was English speaking, and the rest Swedish speaking, a deliberate choice since we wanted to see if there were any language dependant factors involved in route descriptions.

For each subject, we first asked them to describe their experience of Stockholm and whether they had been frequently exposed to describing routes to people and if so, if they thought that they were good at describing routes. The subjects were then given a pair of a starting point and a destination and were asked to do the following:

1. First find a route between the two points. Either 'in the head' or using a map provided by us. Subjects were encouraged to think aloud during this search.
2. Give a verbal route description of the chosen route to another citizen navigator (one of the authors). The map was taken away so that no "pointing" at the map would clutter up the results.
3. Give a verbal route description of the chosen route to a "tourist" driver (the other author).

(Throughout the rest of the document, we shall refer to the experimental leader who played the role of citizen simply as *citizen*, and the other experimental leader will consequentially be called the *tourist*.)

The order of 2 and 3 were varied and the subjects were allowed, but not encouraged, to chose different routes for the citizen and tourist. In some cases, we postponed either 2 or 3 until a few more pairs of starting points and destinations had been explored, in order to see whether the mere fact that the description were given right after one another would influence the descriptions themselves. The subjects were allowed to ask any questions they wanted about the knowledge held by any of the experimental leaders, or upon other issues, like whether the route should be optimal for rush-hours or not, if the route was to be legal or not, etc.

Finally, the subjects went through debriefing were we explained the purpose of the experiment. The whole session was video-taped.

We chose the six pairs of starting points and destinations to allow subjects variation in route choice and road size chosen: we wanted to investigate the conditions under which certain routes were preferred or differently described.

2.1 Stockholm as a Testing Ground

Choosing six pairs of points so that there would be alternative routes posed a problem: Stockholm is situated on the water, see figure 7 page 12, and geographical boundaries constrain free route choice in many directions. In addition, smaller roads in Stockholm often are

for one way traffic only, and many are reserved for local traffic use. The main traffic is required to follow major thoroughfares and avoid passing through residential areas, though restrictions are not always stringently adhered to. Many of the routes described to us violated the local traffic ordinances. Several of the subjects complained that the routes chosen were "impossible" and "too difficult", partly because the routes angled through the city on an East-West axis, and partly because we had chosen areas with extensive traffic planning restrictions.

2.2 Hierarchy

Using ideas from [Pailhouse, Streeter] we identified four hierarchical levels applicable in Stockholm. On the lowest level we placed small roads, used exclusively for residential and local traffic. On the next level we placed connecting roads. On the third level we placed roads with more than one lane, except highways. Finally, on the fourth and highest level, we placed highways and expressways.

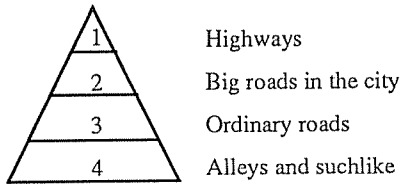

Figure 1. The hierarchy of roads used in the experiment.

The starting and destination points where chosen so that routes that were likely to be chosen between the two points, would differ in terms of hierarchical level of the roads involved.

2.3 Patterns

We analysed routes chosen with respect to which "pattern" they adhered to. We had beforehand decided on three possible "patterns", A, B and C: shown schematically in figure 2. Pattern A is driving out of an area, driving on a bigger road for some time, and then driving into an area. Pattern B is driving out from area, driving on several bigger roads, possibly connecting these bigger roads via small roads. Pattern C is driving on small roads all the time.

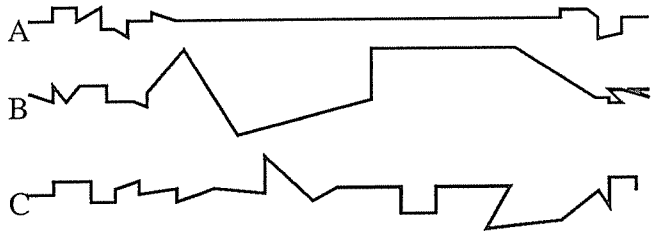

Figure 2. Patterns of routes.

2.4 Distance

We chose the six start/destination pairs to be able to determine the effect of distance on the description. Two of the pairs have similar or identical starting points, and differ mainly in the distance to the destination.

3. Expectations

Why did we choose the properties of the starting points and destinations this way? One concern of ours, was that the results obtained from this study should be implementable. We were therefore foremost looking for that kind of properties, and the above mentioned all fulfil that criteria. Otherwise, we were inspired by the results from the prestudy [Höök], which clearly indicated that some underlying general principles could be extracted from human descriptions. The ideas of patterns, were also drawn from the work of [Elliott and Lesk, Streeter and Vitello], which clearly indicates that humans strive to chose routes so that they follow pattern A. [Pailhouse] has defined three levels of road nets and corresponding search strategies that driver in Paris make use of. From his study (and [Streeter]) we got the idea of a hierarchy of roads.

3.1 Chunks

From the prestudy [Höök], we had some ideas as to what a route chunk would be. For instance, the complicated issue of how to get onto a big road in pattern A, would be compiled into one chunk, and expressed as "get down to Strandvägen". The patterns could be used as predictors of which chunks, and how many, a route description would consist of.

We expected a hierarchy of chunks, so that a description could be depicted and you could go from a very high level description with large chunks (each consisting of several roads), and then construct a new description where those large chunks had been broken it into smaller chunks, which in turn could be broken into even smaller ones, and so on.

We did not expect that chunking would be used with the tourist. That is, we expected that no roads would be skipped from the description.

3.2 Hierarchy

The hierarchical level of a road determines whether it will be mentioned or not. The higher the hierarchical level, the more likely it is that it will be mentioned to the citizen. Every road would always we mentioned in some form to the tourist.

3.3 Grammar

We were also hoping to explore the kind of concepts people use when they describe routes in order to get ideas of how to generate, automatically, verbal descriptions of routes. We expected to find a restricted language of route descriptions; a limited set of expressions with quite definite rules of how these expressions could be combined.

3.4 Route choice

If there are several possible routes between two points, we expected subjects to sometimes choose routes that are more easily described and/or more easily followed for the tourist.

We expected subjects to either chose different routes for goals along the same line but at different distances, or to change their route descriptions so that you would get approximately the same number of chunks irrespective of the fact that the descriptions should be the same for the first part of the routes that they had in common.[1]

4. Results

As we shall see some of the anticipations could be confirmed but others had to be modified. We also found concepts that needed to be added to get a full description of how declarative descriptions work.

The influence of hierarchical level proved to be an important factor. We confirmed that the route descriptions follow a pattern usually consisting of driving from the starting point to some known big road, and then driving off the big road to the goal point. The subjects also chose different roads for the tourist and the citizen, sometimes explicitly stating that the reason was that the route described to the tourist was more easily described.

On the other hand, we were not correct in the assumption that the numbers of chunks mentioned would be kept the same for different routes along the same line but at different distances. We were also wrong in the idea of a hierarchy of chunked descriptions. Instead we found some really interesting properties of declarative descriptions, some of which explain when and why something is turned into a chunk.

We were also able to construct a grammar that together with some "heuristic" rules defines the route description language.

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[1]The idea was drawn from the fact that people only keep 7±2 items [Miller] in their short term memory at one time. We expected the subjects to be limited to this, which of course, they were not due to the interview situation. Instead, it was the listener, i.e. the interviewer, who was limited to 7±2 items that (s)he could remember of the route descriptions given by the subject.

4.1 Three kinds of descriptions

When analysing the experiment we found three different kinds of descriptions, one more than we expected. Firstly, there is the tourist description which we call the *procedural* description for reasons we will explain below. There are two kinds of descriptions aimed at citizens, one which we could obtain just from taking the procedural description and crossing out some of the information, hereafter called the *mixed* description, and another based on an entirely different way of thinking about the routes, which we call the *declarative* description. In figure 3 we can see the difference between these three kinds of descriptions. (The example descriptions have been paraphrased according to the grammar in figure 5, for a full transcript of the example turn to appendix 1.)

Tourist	Mixed	Citizen
Drive Valhallavägen past two roundabouts up to a small "refug" that "stands out into the street a little" on Valhallavägen, where you turn left onto Artillerigatan. Drive it all the way down to Karlavägen where you turn right. Drive Karlavägen which is a boulevard past a park on your left-hand side up to the second left after the park where you turn left on Rådmansgatan. Drive it down past two red-lights, all the way until Sveavägen where you turn left. Drive immediately right onto Tegnérgatan. Drive up a hill to Tegnerlunden.	Find your way up to Valhallavägen. Drive Valhallavägen up to Artillerigatan. Drive Artillerigatan down to Karlavägen where you turn left. Drive Karlavägen up to Rådmansgatan where you turn left. Drive Rådmansgatan down to Sveavägen where you turn left. Drive up to Tegnérgatan where you turn right. Drive up the hill and there is Tegnerlunden.	Drive Karlavägen to Rådmansgatan. Drive Rådmansgatan to Sveavägen.

Figure 3. From Gustav Adolfs kyrka to Tegnerlunden in Stockholm; tourist, mixed and declarative descriptions.

The character of the procedural description aimed at the tourist (see also section 4.2) is foremost that it is a description of a *procedure*, namely, how to drive from A to B. Every road in the route is mentioned, and the subjects try to find properties of the road that the tourist can use for recognition. Subjects will even try to choose the route so that it contains as many recognizable features as possible.

The mixed description seemed to come up whenever the subject felt that the citizen interviewer did not know the route he was about to describe. The route could contain some new twitch not commonly used, or it could be that a part of the route was at a lower hierarchical level than the rest of the route. Usually, this kind of description was only used for a minor part of the whole route, but sometimes the entire route would be explained at this level. This kind of description is foremost characterized by the fact that it used 'spatial markers' like 'left', 'right', etc., and that we could obtain this description simply from crossing out certain extra information, like landmarks, lane information, etc., from the procedural description. Usually, no *objects* (roads, intersections or landmarks) were skipped from this description.

The declarative description, is most easily characterized as attempts to only mention enough road names to exclude any other possible route, or rather any other route that a citizen could possibly have chosen. It is a kind of reflection of the search space that the subjects traverses in order to decide upon a route. All the intersection and some roads have disappeared from this description, and there are not 'spatial markers' left.

4.2 What Does A Procedural description Look Like?

A procedural description can be seen as a sequence of identify-act instructions. Firstly, a point along the route is identified and then the action that should take place at that point is mentioned. Of course, the main place where actions happen while driving is in intersections. Thus intersections are central to procedural route descriptions. Actions that happen in intersections are to make a turn or to go straight through it, see examples 1 and 2 in figure 4 (the examples in figure 4 will be used throughout this section).

In procedural route descriptions we also found two other kinds of actions, namely to continue to drive along a road, and to pin-point a position. We call those the maintain and placement actions.

1. "Follow Karlbergsvägen until S:t Eriksgatan. Turn left there.
2. "Follow Odengatan until you get to the intersection Sveavägen/Odengatan. Continue on Odengatan."
3. "...you will get to a large roundabout: the Brommaplan roundabout. You will have a OK gas station to your right. And to the left you will have the Brommaplan bus depot. And you will come in and you want to turn left. Circle around the roundabout and make a left."
4. "... and to the thir... second roundabout after the Traneberg bridge. You want to make a left."
5. "And you go another two blocks up to the first traffic light. The first traffic light is across from a open area with a work of art you will recognize: a da Vinci thing."
6. "... until you get to a large intersection with a kiosk. To your left. On the other side of the intersection you will see a kiosk. Make a left there."
7. "... after you have passed a pretty big street called Engelbrektsgatan - there's a pharmacy there, for instance - ..."
8. "And you will come out to big road, which you will make a right turn onto ..."
9. "Follow Sveavägen all the way to a huge four-way intersection."
10. "You will get to a, what could one call it, a boulevard: like a very... it has two lanes in each direction, and a wide strip in the middle. With trees and parking and stuff."
11. "...as soon as possible make your way over to the left turn lane, to make a left turn..."
12. "You can continue along that road, past a large park on the left. All the way past that park. Then there's a slight kink in the road. Carry on on the same road. After a while that road will join another main road."
13. "Follow Roslagsgatan for some distance: say 500 meters. I would guess you pass six or seven intersections, and you will have to keep on the look-out for Ingmarsgatan..."
14. "First there is a left in to Sveavägen, and then immediately right from Sveavägen."
15. "Turn right in to Folkungagatan and you will go five or six blocks towards Medborgarplatsen."
16. "If you go north, you will come out pretty soon: you will have an incredible view of Stockholm. You are on Katarina hill. And you follow the slope you come out on there, which will slope down towards Slussen, with a view all along, on the edge of Södermalm."

Figure 4. Tourist route descriptions taken from the interviews (not paraphrased).

4.2.1 Identifying intersections

There are several methods of identifying an intersection. The most common way of identifying an intersection is by identifying the *intersecting road* (example 1 and 2 in figure 4). Another methods is to identify it by *name*: "Brommaplan" (example 3), but very few intersections have names in themselves, and if they do, the names only very seldom are poster. Brommaplan, for instance, does not have its name posted.

The *type* of an intersection can be used for identification: "a roundabout" (examples 3 and 4). If the intersection is of an unusual type it is more likely to be used as a identifying feature: roundabouts, T-crossings, forks, and merges are all used in the interviews. Here we found the only result that indicates any difference between Swedish and English: in Swedish there are no names for forks and merges. Forks and merges are very noticeable when they occur along a route, and need to be mentioned. It took some effort for the interview subjects to clarify in Swedish exactly what they meant when they were describing the route to a tourist. The type of a intersection as a describing feature can only be done if no other similar intersections occur on the same route.

Intersections can also be referred to by using *landmarks* situated near or in the intersection, (examples 5 and 6). Landmarks have been defined by [Lynch]:

> Landmarks are usually a rather simply defined physical object: building, sign, store, or mountain. Their use involves the singling out of one element from a host of possibilities. Some landmarks are distance ones, typically seen from many angles and distances, over the tops of smaller elements and used as radial reference. ... Other landmarks are primarily local, being visible only in restricted localities and from certain approaches.

The *size* of the intersection is sometimes used (example 6 and 9), but this is derived from the hierarchical level of the roads intersecting. An intersection is referred to as large when the intersecting road is at least as large as the street being traversed. One method that quite often turned out to be faulty, was to identify the intersection by the *number* of intersections before it (example 3, 4 and 14). Sometimes subjects would use several of these methods to identify the intersection (example 3 and 5-7). These methods can be (partially) ordered, so that name of intersection is most important, then comes type, landmark and size and thereafter intersecting road and number of intersections.

4.2.2 Identifying roads

Roads need to be identified as well. Roads are identified by *name* (any example) by *size* (example 8) or by *type* (example 10). The priority between the three is somewhat different from the identification of intersections. The name is very important. Even if the name of a road is new to a tourist it will be used. The fact that our subjects were allowed to use a map while planning the route may have influenced this [Gäredal et al.].

Lane information is very seldom used at all, but when it is it seems to take on two different functionalities. It is either a description of a road to help determine the size (example 10) or it is used to describe a turn in more detail (example 11). In our study relatively few routes make use of highways. Highways would probably generate more lane information.

4.2.3 Maintenance and placement actions

Beside informing about an action to be taken in an intersection, actions can be indications about how far to go to along a road. There are several different ways for indicating distance: number of blocks passed, distance in kilometres, or general expressions like "for a bit", "all the way", and so forth. These actions are not as much an instruction to do something, to initiate a new action, but rather to maintain a certain action, driving along a road, up to a choice point, an intersection (examples 12-15). They are needed whenever the road is going to be followed for an unusually short or long part.

The third type of instruction we find is a *placement* action: an instruction that explicitly anchors an abstract description to a location: a description of a place, an intersection, or a view. Placement instruction can be compositions of several landmark references. Placement actions tend to occur in the beginning of procedural descriptions, and then, later in the interview, when some characteristic object or view shows up, most often an object that is so visible that it absolutely must be mentioned (examples 3 and 15). In the latter situation the placement actions serve as a pause in the description. After the pause, the last part of the trip is often repeated.

4.2.4 Beginnings and ends

The unusual nature of the interview situation in which the descriptions are given (describing several routes, sitting in a room far from the places to be described, in front of a video camera) will influence several factors in it. A safe assumption is that the initial part of a route description definitely is expressed different than if given on the road. Several of the subjects suggested that if they had been at the spot, being confronted with a person asking for directions, they would have pointed in a direction to get the driver going.

In the interviews, tourists tended to be guided out from the starting point, and also got placements instructions for the starting point. The subject assuming that the tourist did not know what the starting point looks like.

Sometimes the end point would only be described by "then you follow the signs", which is only possible when the end point is big enough to be posted. Otherwise the whole end part of the trip was described and a placement instruction was given so that the tourist would know when he had reached the end.

4.2.5 Defining a grammar for Observations

Bringing together what has been said above we find we have a small grammar for route descriptions, see figure 5. The strings it describes do not completely correspond to acceptable route descriptions, but our current goal is not to be able to generate good procedural descriptions, only to describe them as given by humans.

It turns out that most regularities of tourist route descriptions can be captured even with this relatively crude formalism. A small subset of natural language is involved. If we do not mind

the monotonous nature of the resulting dialogue, a simple template grammar will actually produce procedural descriptions.[2] In a sense, the grammar strings are not a surface structure, but a deeper structure which simply contain a minimal amount of information to be realized in any way deemed fit. To some extent, it is language independent, one of the interviews was conducted in English with a native English spoken person, and the resulting material was completely compatible with the grammar.

Route_descr →	**Start Instruction* Goal**
Instruction →	**Action** | **Maintain** | **Placement**
Start →	**Placement**
Goal →	**Placement** | **Sign**
Action →	drive **Road (RoadId)** **(Until Intersection (IntersectionId**)) (where you **Do**) **(Direction)** (into **Road (RoadId)**)
Maintain →	drive **Road (RoadId)** {past **Landmark** | through **Area** | **Sign** | towards **NSWE** | until namechange to **Name** | **Distance**}
Placement →	You can see {**Landmark** | **Road** | ... }
RoadId →	which has **Feature**
Until →	until | all the way until | right to the end | ...
Intersection →	**Name** | **Type** | **Size** | an intersection
IntersectionId →	which has **Feature** | which is by **Landmark**
Do →	turn left | turn right | follow the traffic | go right through
Direction →	towards **Area** | towards **NSWE** | "down" | "up" | **Sign**
Distance →	**N** {meter | intersections | red_lights | blocks | ... } | for a while | for a short while | directly
Sign →	following sign towards {**Area** | **Road** ...}
N →	1 | 2 | ...

Figure 5. A descriptive grammar for tourist route descriptions.

4.3 Differences between tourist and citizen

Given that we know how a procedural description looks like, a mixed description can be obtained by deleting irrelevant information that the citizen navigator knows. The basic structure of this mixed description is not identify-act but rather identify as simple as possible and then act. By identify as simple as possible is understood that no hierarchical information, descriptions of landmarks, traffic, traffic regulations etc, are included in the description. What will be left is simply the backbone of a route description; "drive Road1 until Intersection1 turn left and drive Road2". There are a few exceptions from this pattern. The road name can be substituted by a known citizen landmark, and subjects sometimes feel inclined to describe a road on a very low hierarchical level as "small". Otherwise, mixed descriptions can be obtained by removing the "IntersectionId" and the "RoadId" from the grammar rule "Action", and take away the placement and maintain instructions from the grammar in figure 5.

As indicated above, declarative descriptions on the other hand, are fundamentally different from procedural descriptions. We cannot simply take a procedural description and cross out irrelevant information and obtain a declarative description.

Route_descr →	**Start Instruction* Goal**
Instruction →	**Citizen**
Start →	[]
Goal →	[] | **Sign** | **Mixed**
Citizen →	drive **Road** | drive past **Landmark**
Sign →	following sign towards {**Area** | **Road** ...}
Mixed →	see above.

[2] For an example of dialogue that is paraphrased using this grammar see the three example descriptions in the beginning of section 4.1.

Figure 6. A descriptive grammar for citizen route descriptions.

Following the concepts for the procedural description, we see that actions for citizens do not happen in intersections. Instead, it seems to be the case that we have a more *declarative* description, that does not explain how you get yourself through a number of intersections with left and right turns. The description will instead consists of a number of *citizen* instructions that in most of the cases is simply a road name, formalized in the grammar in figure 6. Sometimes the subjects will say "drive Karlavägen", but sometimes, they even exclude the action of driving on the road and state the road by itself "Karlavägen" or "you take Karlavägen", cf. figure 3 in section 4.1.

4.3.1 Gaps in the declarative descriptions

In the procedural descriptions, every road, every intersection where action should take place, and some of the landmarks were mentioned. In the declarative description, all the intersections, and almost all the landmarks disappear. It is even the case that some of the roads are left out. Which ones? The issue of which roads are left out is a complicated one. In table 1 we have counted all the times one or several roads were not mentioned in the descriptions. We have differentiated between when roads where left out in the beginning of the route, the middle of the route or the end of the route for each of the six roads. As you can see, tourists (almost) never get gaps in the middle of the trip. On a few occasions the procedural descriptions had gaps in the beginning or end of the trip, as for road2 where three subjects left out the last road or two.

	Road1			Road2			Road3			Road4			Road5			Road6		
	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E
Novice	1	1	1	0	0	3	2	0	0	1	0	0	1	0	0	0	1	0
Expert	3	7	8	4	4	7	6	3	4	3	2	2	6	1	2	4	6	0

B = beginning of trip , M = middle of the trip, E = end of trip

Table 1. Gaps in the route descriptions.

For the citizens, many more roads disappear from the descriptions. Firstly, subjects seem to take away the first part of the trip. The subjects apparently assume, that the reason for asking about a route between the starting point and the destination, is that you know where you are, but you do not know exactly where the destination is situated. So usually, the first one or two roads are taken away. The principle seems to be that all roads before a road with quite a high hierarchical level, can be taken away, if the number of roads is sufficiently small (2-3 roads).

The last part of the trip is not described with the same pattern, instead the simplified declarative description is often used by the subjects. An exception seems to be when the goal is on a very high hierarchical level or close to a road which is, as we can see with the roads number 1 and 2 where eight respectively seven subjects left the last roads out. It can be observed that the hierarchical level of the starting point does not seem to affect whether it will be described or not, even when it is very low. See roads 2,3,5 and 6 for roads with low hierarchical level of starting point, where as many as 4,6,6 and 4 subjects respectively have left roads out in the declarative description.

As we see in table 1 there are also gaps in the middle of the description where roads have been left out, and the principle behind those gaps is much more complicated to depict. It seems like that the roads that *are mentioned* serves the purpose of excluding other possible routes. By other possible routes, we do not intend any possible route, but rather any route that would have been a likely candidate to get to the destination. This does not seem to be the whole explanation, it also seems like the subjects add some roads the make the route description complete, and that those roads are usually on a high hierarchical level. Any road which is only going to be followed for a minor part of its length, or that is on a lower hierarchical level than the rest of the roads, are only mentioned if they give the route an unexpected twitch or if they lead to the goal. The roads that are to be driven to their end are usually mentioned.

Subjects abandon this pattern when a 'strange' route has been chosen. Something seems to be a strange route whenever roads on a low hierarchical level are chosen, or when the chosen route is much longer than the crow-flight distance. The mixed kind of description will then be used.

As we see the notion of patterns can serve as a predictor to cover most of these irregularities. In a pattern A route, only beginnings and ends can disappear. In pattern B and C, we need to look out for places in the middle of the trip where roads can be taken away.

4.3.2 Landmarks in procedural and declarative descriptions

Subjects use landmarks in quite different ways for citizens as opposed to tourists. The obvious difference should be that some landmarks are only visible/usable to a driver if she knows the city. For instance, one of the subjects described a road to be one quarter away from a big intersection known as Roslagstull, where the driver at that point, would have been unable to see Roslagstull. Another subject talked about a portion of the road as Tre Portars backe (Three Gates Hill), which is a name that is derived from the fact that there used to be three bridges over that road, but nowadays the bridges are no longer there.

As seen in table 2, tourists in general were provided with a lot more landmarks than were citizens. In the table we have divided landmarks into six groups. The first group, *Stockholm*, is landmarks that are only comprehensible to a citizen of Stockholm. The second group, *geographical* landmarks, is mainly hills, parks and other similar features. The two groups that possibly should have been included in the geographical landmarks group are the *surroundings* and *traffic* landmarks. The surroundings group consists of description of views like "you will follow water to your left", or "then you will have a view office buildings all around you". The surroundings group differ from the geographical group in that it describes objects that in a sense are continous, while the geographical objects are points. The traffic landmarks on the other hand, are descriptions of the route in terms of traffic regulations, or the number of lanes, or suchlike. The *building* landmarks are the ones that are most typically landmarks in the Lynch sense. They are usually visible from the road. In this group we have also included hotels, pharmacies, bus stations, etc., that in some sense are buildings and recognizable to everybody. Finally, we have made *bridges* into their own group since they in a sense belongs to both the traffic, geographical and buildings groups and also are so frequently occuring in the descriptions due to the infrastructure of Stockholm.

	Sto	Geo	Surr	Tra	Bui	Bri
Novice	0	45	34	70	80	28
Expert	16	14	2	13	24	17

Sto = Stockholm, Geo = Geographical, Surr = Surroundings,
Tra = Traffic, Bui = Buildings, Bri = Bridges

Table 2. The number of times landmarks were mentioned in the route descriptions.

With tourists we found that landmarks are used for three different purposes. Firstly, they make it possible for the tourist to recognize an intersection where an action is supposed to take place (example 6 in figure 4). Secondly, they can be used to keep the tourist on a certain road for a while, in the maintenance instructions (example 12). Thirdly, the placement instructions usually consists of one or more landmarks (examples 3 and 15), used in a more checkpoint manner, to indicate that a new series of instructions will follow after that checkpoint.

With citizen navigators on the other hand, landmarks are used rather as choice points instead of recognizable items. Instead of using a road name a landmark that uniquely determines that road can be used. The landmark is therefore not described in any detail, but is only referred to by name.

How often are landmarks used? For the tourist, it seems to be as often as possible. Whenever there is a noticeable landmark in an intersection, it will be mentioned. An intersection without landmarks, is described by some other means, like name, intersecting roads, hierarchical level, traffic intensity, or something else. Landmarks along the road, only appear when you have to travel for some longer time on that road, as in maintenance actions.

In the declarative descriptions, landmarks quite frequently turned up when the subject could not remember the name of the road, or when the landmark was such a well known item that its name would supersede the road name.

4.3.3 Hierarchy of roads and intersections

In our assumptions (section three) we assumed that hierarchical level of roads would play a role in the choice of roads and the way they are described. It turned out that our subjects were so aware of the hierarchical level of objects that they even would tell the tourist about the hierarchical level of roads or intersections in their descriptions.

The citizen was usually not told about the hierarchical level of roads or intersections, which is natural since the subjects assumed that they knew it from the start. The few times it occurred was whenever the hierarchical level of the road was unusually low. Otherwise the subject probably assumed that the citizen knew the hierarchical level of roads. In table 3 we have put together a list of how many times the hierarchical level was mentioned to the tourist and the citizen. The third use of hierarchical information, "past N intersections", is when an intersection is identified by a phrase like "you driver past N small intersections until a big one".

	Intersection		Road		Past N intersections
	High	Low	High	Low	
Novice	11	0	11	2	10
Expert	0	0	0	2	0

Intersection = intersection described using hierachical evaluation, Road = road described using hierarchical evaluation, Past N intersections = hierarchical information used to determine where an action of turning should take place

Table 3. Use of hierarchical information.

4.4 Route Choice

One of the pairs of starting and end points did not allow different route choices, but the other ones did. They were chosen so that the possible routes between the two points would differ in terms of patterns, see figure 2 on page 3. We found that in quite a few cases, the subjects would chose different routes for the tourist and the citizen, see table 4. Usually, when they choose different routes they would mention the fact that they did so, and sometimes why.[3] Usually the reason was that the route chosen for the tourist was more easily described.

	Road1	Road2	Road3	Road4	Road5	Road6
Different routes	2	4	3	5	0	2

Table 4. Numbers of times different routes for chosen for the citizen and the tourist.

Now, what makes a route more easily described than another one? [Davis and Trobaugh] have defined some properties of easily described routes. They say that an easily described route should not contain too many turns, and it should, when possible, go via important landmarks. One of our subjects explicitly verified the second property. He consequentially tried to get the tourist past big landmarks that were visually attractive. The first hypothesis could also be verified. The tourist route was usually more straight ahead, included fewer turns.

We would like to add another property that has to do with hierarchical level of roads. Our subjects frequently tried to chose roads that were on the highest hierarchical level when possible. The concern seems both to be that the route should be the shortest in terms of time, but also that, especially tourists, should not get lost. A bigger road is easier to recognize, it has

[3] From one interview: "*I am thinking about whether I should tak... try to explain the same road a gave Jussi, or if there is any easier one. It is not certain that ... It is not certain that the shortest route is the best to explain, right?*"

better signs, and you can usually travel on it longer than on a road on a lower hierarchical level.[4]

In table 5 we have illustrated the difference between the tourist and citizen routes going from Katarina church to the university (road2 in table 4 above) in those cases where different routes where chosen by the subjects. The numbers refer to the hierarchy of road types described in section 2. You can notice that the number of roads appearing in the citizen route are slightly higher, but the interesting difference is that the hierarchical level is in general lower for the citizen.

	#obj	#descr-obj	Hierarchical level of the roads involved
Subject#1: Expert	12	4	4-3-2-3-3-2-2-3-2-2-1-4
Novice	10	10	4-3-2-1-1-1-2-3-1-4
Subject#2: Expert	10	5	4-3-1-1-1-2-3-2-1-4
Novice	9	8	4-3-2-2-3-2-2-1-4
Subject#3: Expert	12	5	4-3-2-2-1-1-2-3-3-2-1-4
Novice	10	10	4-3-2-2-1-1-2-4-1-4
Subject#4: Expert	16	8	4-3-2-3-3-2-2-2-3-2-2-2-2-3-1-4
Novice	10	8	4-3-2-2-1-2-2-3-1-4

#obj = number of roads in the chosen route, #descr-obj = number of described roads

Table 5. Differences in number of roads, number of described roads and hierarchical level of roads in tourist and citizen routes.

Different routes were also quite frequently chosen for goals that were along the same line, but where one goal was much further away than the other. An interesting pattern becomes apparent. When a route is chosen, it seems like humans first try to backtrack from the goal in the direction of the starting point, to a well-known spot or road to which they know that they can find their way from the starting point.

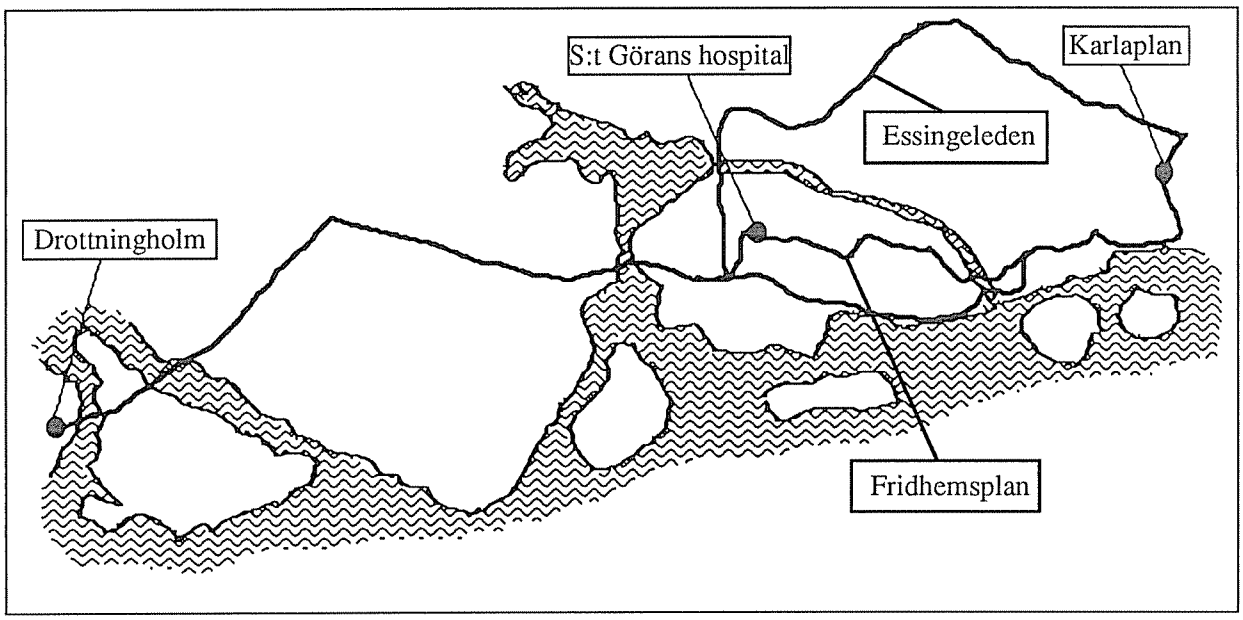

Figure 7. Going from Karlaplan to S:t Görans hospital or Drottningholm.

Now, in figure 7, we see that the one of the goals that we chose for our study, lies very close to a big road, marked as Essingeleden. This big road was very frequently chosen for the second goal, Drottningholm, but not as often for the first goal, S.t Görans hospital, that lies so

[4] On the other hand, one person rejected a bigger road for estethical reasons. He felt that a tourist should go on beautiful roads, and also that a big road has the disadvantage of being to hard to get off at the right place. If you miss an exit you might sometimes have to travel several kilometres before you can get off and turn back.

close to it. We found that since chosing this road would mean going in the wrong direction a couple of blocks in the direction from the starting point, subjects were unwilling to make this connection, both for tourists and for citizens. Instead they connected the point Fridhemsplan with the goal, and tried to find a route from the starting point to Fridhemsplan. The route through Fridhemsplan is much more complicated both to describe and to ride. Essingeleden is a route at the highest level of hierarchy, and the speed-limit is here 70 km/h instead of 50 km/h which is the normal speed limit in the city.

To some extent the way that the subjects construct the routes in their minds, will manifest itself in their description. In the example above, Fridhemsplan would be mentioned as an important point in the declarative description if that route were chosen.

Another pattern was found with the second pair of goals that were situated along the same road. The closest goal, Ingmarsgatan, was this time very close to the road that people normally used for the second goal, Stockholms University. Different roads were still chosen for the two goals, but the consideration did not seem to depend upon the fact that you would have to travel one block 'back' from Roslagstull, in order the reach the first goal from the chosen road. Instead the ability to describe the road in an as unambiguous manner as possible was the criteria of whether one route would be chosen before another. One route is much more difficult to describe since it involves more objects, and the objects are at a lower hierarchical level. As a consequence this route was more seldom chosen, and usually only chosen for the citizen.

4.5 Why these descriptions?

Why do people describe the routes as they do? The issue seems to be a mixture of how the route is chosen, which mainly manifests itself in the declarative description, and whom the subject thinks he is directing himself to.

If the subjects believes that he is directing himself to a tourist, you get the sense that the subject is mentally tracing the route, observing features as she goes along. The subject is constantly placing herself and the tourist 'in' the route with expressions like "then you will be at ... ", "then you will see ...", "then you go under a ...". When doing the interviews, it was obvious that the subjects were trying hard to visualize the route in order to give as good placements descriptions as possible. One of the subjects even talked about the difficulty he experienced in visualizing certain parts of the route.[5]

In the study, we could see that when subjects try to visualize the route, the description not only tends to be much longer, it also takes much longer time to describe the route. It seems that visualization is a costly, cognitive process.

If the subject is directing herself to a citizen the descriptions seems to be much closer to how the subject has constructed the route in her mind without visualisation. You get the impression that she is viewing the city from above, seeing important roads and points where choices must be made.

5. Automatic generation of messages

We have described the study and the kind of principles we could extract from it. What can we do with these principles? We would like to do a 'sensible' implementation of these principles. Since 'sensible' is not necessarily equal to how humans describe routes [Riesbeck], we need also to look at how humans understand and misunderstand route descriptions. Luckily, there have been quite a number of such studies [Streeter and Vitello, Labiale, etc.]. We know that humans are bad at reading and understanding maps, bad at estimating distances and number of blocks, that humans tend to forget instructions with more than 7±2 items, etc.

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[5] "I am mostly trying to visualize the route myself at the moment. And see... And count the... The difficult points. The points that you could generally worry about: directions, difficult crossings. [...] OK. I think the difficulty is for me that I'd like to picture the route in front of me as I describe it. That's what I have difficulty doing."

Let us set up a scenario of how a route guidance interface could look like. Let us assume that we shall only be able to provide the most simplistic kind of user modeling, one where the user herself indicates which of two modes she wants to use, a kind of *static* user modeling.[6]

The first mode, the tourist mode, would not give any route information to the driver prior the trip, which is easily justified by the fact that the tourist does not know the city and would not be helped by getting information about things she cannot see yet. Instead very exact instruction would be provided during the trip, helping the tourist through each intersection. For instance, parts of the LISB interface could be a nice alternative for the during trip information, see [von Tomkewitsch]. The tourist mode would not contain any explanations as to why a certain route has been chosen. The tourist is simply interested in getting to the destination using a nice and easily followed route.

The second mode, the citizen mode, would provide somewhat a different approach. Firstly, it would give route information before leaving. This would help the driver to get a sense of where she is going. If the driver is very experienced, it could even be the only way the route is presented.

During the trip, we can imagine two different approaches. One would be to give the same kind of instruction that the tourist is provided with, which might be tedious for the citizen to listen to. The other approach would be to use something similar to the mixed description divided into manageable parts. Further investigations with an implemented system would provide more insight into what kind of solution might be best.

For the purpose of commuters, or very experienced drivers, we might even consider giving explanations before the trip starts as to *why* a certain route has been chosen. How to do that requires a lot of insight into how people reason about the mechanisms that control traffic intensity, and it might even require that the system knows which routes are likely to be chosen by humans and which are not. We believe that especially with commuters, it will be necessary to investigate this further, for a more lengthy discussion see [Lindevall and Höök].

In table 5 we have summarized our view. We could imagine a situation where the driver would switch on or off citizen mode, to obtain all three levels of information. If the system is operating in tourist mode, only on-road information will be obtained. If citizen mode is on, no during trip information will be provided. If both are on, both kinds of information will be given.

	Before	During	Explanation
Tourist	No	Yes	No
Middle	Yes	Yes	Yes
Citizen	Yes	No	Yes

Table 5. Route guidance for different drivers.

Let us explore the system for plan presentation. Given a starting point, a destination, knowledge of the user's experiences in the area in a user model, and a database of the route to be traversed the strategy for description will be based on a three step process, see figure 8.[7] First the planner constructs a route. It consist of nodes and segments, where the nodes roughly corresponds to intersections, and the segments to roads. The hierarchical level of the segments is included in the plan.

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[6] We could imagine a situation where the driver identifies herself through a plastic card used as a key to the car, on which we have put a more *dynamic* user model that adapts to the user behaviour, habits and knowledge. There is a lot of research effort put into such dynamic user models, but for the moment it is probably more realistic to use a static user model.

[7] In figure 8 we have left out a number of components necessary for a route guidance system, for instance, a route monitor, some integrated dialogue management, dynamic replanning etc. For a complete picture of the system architecture turn to [Brown et al.].

Secondly, the route chunking mechanisms, using the plan, the user model, and the map database, processes the plan into suitable chunks according to the results obtained in our study. It will in the tourist case change the plan into a "Road1 Intersection1 Road2, Road2 Intersection2 Road3" pattern where the intermediate road is repeated. It will then adorn this pattern with names of roads and intersections, landmarks, lane information, etc., where it is needed. Placement and maintain instructions will be added where needed.

In the citizen case, the route chunking mechanism will change the plan by deleting all the intersections and as many roads as possible. It will also serialise the objects to be described into chunks of reasonable size, and decide which roads to substitute with landmarks or nicknames. Here we will use the same principles as did our subjects, see section 4.3, for instance; which roads to delete will be deduced from their hierarchical level and place in the pattern; all the intersections will be deleted; if an extremely low level road has been chosen, we will describe it if comes in the middle of the trip; the first and last parts of the trip will be taken away, etc. We shall look out for any strange twitch in the plan where we might need to use the mixed description rather than the declarative description. The roads are given names taken from the map database.

Lastly, the output from the generator is fed into a grammar. In view of the fact that the descriptions constitute such a limited subset of natural language, as can be seen from our descriptive grammar, even a relatively small and unsophisticated grammar can be expected to produce satisfactory results.

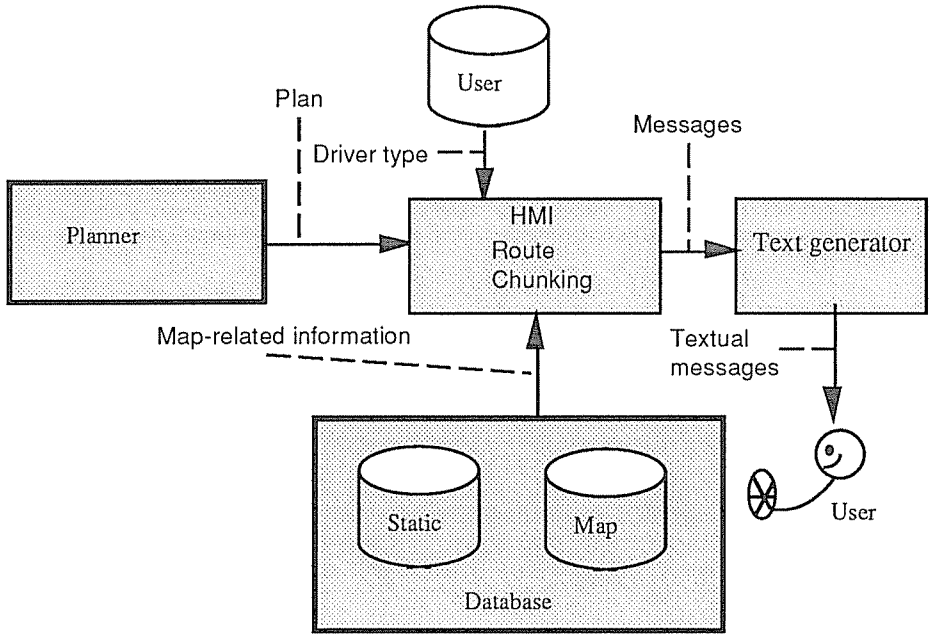

Figure 8. System architecture for the route chunking mechanism.

The output from the route chunking mechanism, is roughly equivalent to a *message* as defined by [Mellish and Evans]. It is a nonlinguistic object, at a more abstract level than the linguistic level. A message is built from a limited message language specifically devised to express a certain domain, in Mellish and Evans case, the planning domain.

Our *message language* is much more limited than [Mellish and Evans] since it only will deal with sequential plans instead of nonlinear, there is only one actor able to perform the instructions instead of several, and the utterances we would like to express are fewer. Still we would like to make our message language rich enough to later on be able to express explanations, and as a basic datastructure for some reasoning when we have dynamic replanning[8].

[8] Dynamic replanning comes into play when the system can replan due to traffic intensity or other variables, a new plan sometimes needs to be presented to the driver. Some reasoning as to how much of this new plan needs to be presented, has to take place.

A *message* is firstly an utterance, but also various ways of combining messages. An *utterance* in turn is either an instruction to perform an action, an explanation of an action, or an expansion of a complex action into subactions, etc. An *action* in our case is what the driver can do while following the route, i.e. turn, maintain, placement or drive actions. We have gathered a suggestion as to what structures might express this in figure 9.

The purpose of the route chunking mechanisms will therefore be to take a plan and decide what is to be said, in what order and to whom, and then produce a message with that information.

In figure 8 above, we have only allowed the user model to influence the route chunking. User modeling is traditionally still regarded as important only for the user interface. It is important to point out that in this case, and many others, a user model should really be allowed to influence earlier stages as well. In this case, it would mean influencing the planning process. If the planner can be adopted for the tourist, so that it produces plans with fewer turns, as in [Elliott and Lesk], and includes roads at higher hierarchical levels, it would indeed be easier to describe the route to the tourist. The citizen would benefit from the shortest route, even if it is hard to describe and follow. In [Lindevall and Höök] we investigate this issue further.

MESSAGE:
utterance
--- see below
time-then(MESSAGE,MESSAGE)
--- two bits produced in sequence, this indicating time order
UTTERANCE:
do(ACTION)
--- instruction to perform an action
now(STATE)
--- indicating that some state now holds (explanation)
expansion(ACTION, ACTION)
--- describing the expansion of an action into subactions
ACTION:
turn(DIRECTION,INTERSECTION,INTERSECTING-ROADS)
--- turn in some directions in a certain intersection from one road onto another
maintain(DISTANCE)
--- keep going on a road for some distance measured in meters, blocks, etc.
placement(LANDMARKS)
--- you will see certain landmarks
drive(ROAD)
--- citizen instruction that can be expanded into the other actions

Figure 9. Some messages, utterances and actions in the message language.

6. Conclusions and future work

We have exposed the underlying principles of citizen and tourist route description done by humans, both in terms of how they are described and, to some extent, why. We have also seen how the actual route choice differs for the two groups.

Furthermore we have indicated how these principles could be implemented and used as an interface to a route guidance system. We believe that the solution we have outlined is good for citizens, but not so good for tourists, but this needs further inquiries. We intend to make an implementation of the ideas, and to use a real world map. This would enable us to test the obtained route descriptions with humans.

In figure 5 above (page 8) we have summarized the tourist route description language. In principle, it says that:

- The basic unit for describing a route is an instruction to perform an action.
- Actions are choices made in an intersection.
- Instructions can also be placement instructions and maintain instructions.

There are some heuristic rules as to when any of the grammar rules comes into play, like for instance, that when describing an intersections, the name of intersection is most important,

then comes type, landmark and size and thereafter intersecting road and number of intersections.

The mixed description (as said above) can be based on the grammar in figure 5 (page 8), by simply removing all the "IntersectionId" and the "RoadId" from the grammar rule "Action", and take away the placement and maintain instructions.

Let us try and summarize the declarative descriptions. Here the grammar rule for the surface language is very simple, see figure 6 (page 8). What is interesting about declarative descriptions is that they are extremely short. The grammar in figure 6 only explains parts of this, that the instruction is not adorned with so much extra information, and is *declarative* rather than *procedural.* The rest of the explanation comes from the fact that roads are left out in the middle of the trip, the start of the trip, and the end of the trip. Those gaps can be expressed in some heuristic rules:

- The first 1 - 3 roads before a road on a higher hierarchical level can be taken away from the declarative description.
- If the goal is on a high hierarchical level, the last 1 - 3 roads can be skipped.
- In the middle of the trip, only roads that help excluding other alternative routes are mentioned, plus some roads that help making the route description 'complete' (these road are usually on a high hierarchical level and it would be odd not to mention them).

There are also some principles for when a switch to mixed descriptions is made. It occurs when a 'strange' route has been chosen. Something seems to be a strange route whenever:

- roads on a low hierarchical level are chosen,
- or when the chosen route is much longer than the "as the crow flies" distance.

Finally, the citizen pattern: "drive Road1, drive Road2 ...", is only changed using a landmark or hierarchical information on a few occasions. The principles seems to be that:

- A road name can be replaced by a landmark that uniquely determines that road when the subject can not remember the name of the road, or when the landmark is such a known item that its name would supersede the road name.
- Whenever the hierarchical level of the road is unusually low, it indicates that a strange road has been chosen, and to emphasise this the hierarchical level of the road is mentioned.

In terms of route choices, the underlying principles seems to be that:

- Tourist routes are chosen by subjects in order to be easy to explain. A route is easy to explain when it is on a high hierarchical level, contains few turns, and goes by important landmarks.
- Routes are constructed by tracing the route backwards from the goal to a point that is easy to connect with the starting point.

In our study, the subjects were asked to give the route descriptions verbally, and it could be argued that we would have found other principles if they had been allowed to draw maps as well. The decision to limit ourselves to verbal descriptions, is due to the fact that quite a large amount of the population is not very good at interpreting and using maps [Thorndyke and Goldin]. The same conclusion was drawn by [Streeter and Vitello]. We also know that the visual channel is highly overloaded already in the driving situation. If the audible channel is used, the visual channel is not cluttered [Davis and Schmandt]. Still, a similar study where subjects are allowed to draw maps as well, would be interesting.

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